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EOLE BALLOON. SUMMARY OF PRINCIPAL TESTS PERFORMED ON BATTERIES FOR THE EOLE BALLOONS

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EOLE BALLOON NO. 70/CT/TA/EB/0.672/EOLE/B. SUMMARY OF PRINCIPLE TESTS PERFORMED ON BATTERIES FOR THE EOLE BALLOONS

S. R. Stevens

ABSTRACT: This report deals with the principle tests performed for the Eole balloon. The mechanical and electrical characteristics were measured at various temperatures. It was found that overcharging eventually caused the battery to dry up. On the whole, the tests, while not of a final nature, are encouraging and indicate that these batteries should perform their function well, provided that they are not overcharged.

1. Description of the Battery

The battery intended for installation on Eole balloon nacelles is made of /1* 10 NiCd cells, the electrolyte (8 cc) being a 10-normal potassium solution.

Each cell is rolled around a tubular support made of fiber glass and wrapped with adhesive tape.

A "flexible" battery is constructed by assembling cells and two end pieces by means of the same type of adhesive tape.

The dimensions of the battery are as follows: length, 1,070 ± 10 mm; exterior diameter, 64 ± 0.5 mm; weight, 970 ± 30 g.

2. Electrical Performance Characteristics

Since the first batteries which complied with the specifications were only recently delivered, only a few tests could be performed and knowledge of these batteries is not complete.

2.1 Conditions for Use of Battery

Charging: the batteries may be satisfactorily charged at temperatures between -30°C and 40°C. The only condition to be met in order to provide correct charging of the batteries is to make sure that they are charged slowly.

*Numbers in margine indicate pagination in foreign text.

θ = 25°C Ic = 160 mA (C/10)

θ = -30°C Ic = 40 mA (C/40)

Discharge: for temperatures between -60°C and 40°C, the discharge capacity is between 0.600 and 1.7 ampere hours. Slow discharging, 30 mA (C/50), is also necessary here for temperatures down to -40°C because of the increase in internal resistance due to formation of ice crystals and the hydrate KOH 4 H 20.

2.2 Capacity as a Function of Temperature

2.2.1 Capacity for Continuous Discharge /2

No systematic evaluation test for capacity as a function of temperature has been performed up to now. Nevertheless, the following results have been obtained:

θ Charging Temperature	I Charging Current (mA)	Charged Capacity (Ah)	θ Discharging Temperature	I Discharging Current (mA)	Discharged Capacity (Ah)
+ 25° C	160	2,24	25° C	320	1,70
- 30° C	40	1,2	- 30° C	30	1,175
- 30° C	40	1,2	- 50° C	30	0,9
- 30° C	40	1,2	- 60° C	30	0,65

Commas indicate decimal points.

2.2.2 Capacity for Pulse Discharge

Discharging conditions: constant discharging current I = 30 mA with superimposed pulse at 0.8 amperes for a duration of 600 milliseconds every

40 seconds. The discharging would be stopped when the battery voltage reaches 0.9 volts during a pulse.

Results: for θ = -50°C, duration of discharge is 12 to 13 hours. For θ = -60°C, duration of discharge is 5 to 5 1/2 hours.

2.3 Behavior Under Conditions of Overcharge

2.3.1 Damaging of Cells by Overcharging

During the overcharging of a cell, there is potassium electrolytes and release of oxygen and hydrogen. The internal pressure of the cell increases. Since the electrodes are placed in a rilsan envelope the increase in pressure produces deformation of this envelope and crushing of the fiber glass support until it breaks.

The process continues until leaks appear at the welds of the rilsan envelope. /3

During the cyclic operation (charging and discharging), the overcharge (potassium electrolyte) results in progressive drying of the cell.

2.3.2 Evaluation of Conditions of Maximum Overcharge as a Function of Temperature

The number of cells whose support was broken was determined for the following cycling conditions: duration of cycle, 24 hours; charge, 12 hours at constant current; idle time, 12 hours.

The following temperature and charge conditions were found:

-θ = -20°C	I charge = 20 mA, 30 mA, 40 mA
-θ = -10°C	I charge = 20 mA, 40 mA
-θ = 0°C	I charge = 40 mA
-θ = 10°C	I charge = 40 mA
-θ = 25°C	I charge = 75 mA

Counting the number of cells whose support is broken after ten cycles permits evaluating the maximum currents which can be allowed for overcharging:

θ = -20°C	Is = 25 to 30 mA

(continued)

θ = -10°C — Is = 30 to 35 mA

θ = 0°C — Is = 35 to 40 mA

θ = 10°C — Is = 40 to 50 mA

θ = 25°C — Is = 75 to 100 mA

2.3.3 Internal Resistance

No specific tests for measuring internal resistance were made. Nevertheless, the following values were recorded during pulse operation:

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θ	I	$r = \frac{\Delta V \text{ Resistance}}{I}$	$\rho = \frac{\Delta V \text{ Resistance} + \Delta V \text{ Polarization}}{I}$
+ 20° C	1,2 A	0,3	0,3
- 40° C	1,2 A	0,3	0,3
- 50° C	1,2 A	0,88	1,33
- 60° C	1,2 A	1,2	2,5

These values apply to a battery with 10 cells at the beginning of discharge.

3. Operating Conditions in the Eole Balloon Project

3.1 Temperature

According to theoretical calculations the temperature of a battery is a function of the following: during the day, as ambiant temperature and reflected light from the Earth; at night, of the ambiant temperature and infra-red radiation from the Earth.

Day: $-25°C < \theta < 25°C$

Night: $-50°C < \theta < -20°C$

Battery temperature was measured during different lights and the values recorded confirm the theoretical calculations.

3.2 Energy Conditions

During the period from August 31 to October 31, the battery will be subjected to the following charging conditions:

Reflection coefficient	Battery temperature	Current furnished by GS (mA)	Capacity furnished by GS (mAh)
0	- 25° C to - 15° C	35 to 45 mA	300 to 500 mAh
0,35	- 5° C to + 5° C	40 to 50 mA	375 to 675 mAh
0,8	+ 20° C to + 30° C	60 to 70 mA	450 to 900 mAh

Taking into account the consumption of the nacelle (200 to 270 mAh, depending on latitude) and of the battery efficiency (not evaluated for this type of cell, but estimated to be close of that of the conventional nickel-cadmium cells), the battery is overcharged every day.

Therefore, the overcharging currents are higher than the maximum allowed /5
current (see paragraph 2.3.2) and consequently, the battery is damaged. In order to prevent this from happening, it is necessary to introduce a charge regulator into the power supply which would perform the following function: detect battery voltage higher than or equal to 15.4 V ± 0.3V; keep the voltage at 14.3 V ± 0.3V.

4. Test Results

4.1 Mechanical Tests

4.1.1 Air Safety

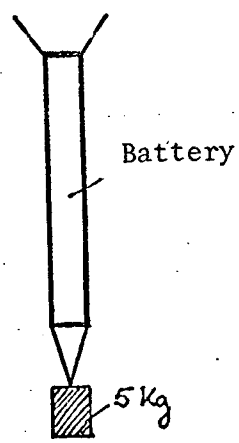
The general manufacturing standards required of the builders are: ratio of mass to length $\leqslant 5$ g/cm; ratio of mass to minimum projected surface $\leqslant 2$ g//cm^2; unit mass (applies to components) $\leqslant 3$ g/cm^3.

Batteries are a particular case which cannot meet the standards, since the mass per unit length is approximately 9 g/cm. This results was obtained after many modifications due to conditions of electrical operation of the battery and to the results of impact against an airplane windshield.

After a series of tests, it appears indispensible that the batteries satisfy the following conditions: weigh less than 10 g/cm; be weakened at the connections between the cells, this would avoid a concentration of mass at the windshield; possess end pieces made of a material which would shatter at impact.

4.1.2 Resistance to Traction

The battery plays no part in supporting the equipment located at the lower portion of the nacelle. (The suspending ropes go through the battery inside the fiber glass support.) Nevertheless, the following traction tests were performed: two batteries are suspended by one end and a weight of 5 kg is attached to the other end, the assembling being exposed to bad weather beginning December 12. Inspection of the mechanical condition was made every 15 days; breakage of the adhesive tape between the top two cells was observed after 5 and 6 months of storage, respectively. /6



4.2 Thermal Testing

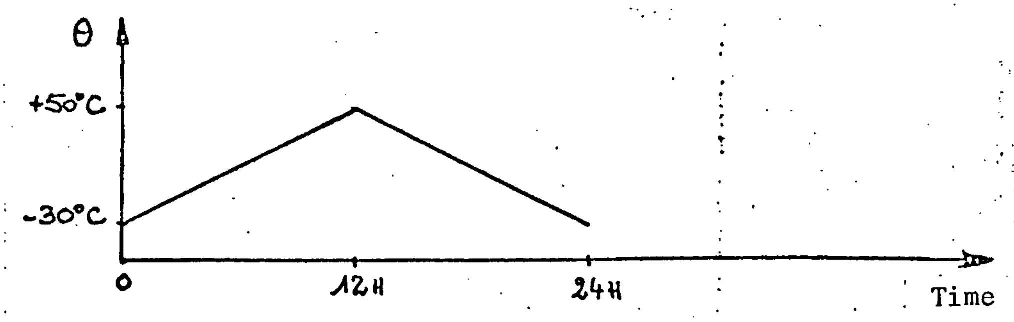
4.2.1 Thermal Cycling

Ten thermal cycles were performed on a discharge battery: duration of cycle, 24 hours (12 hours at -80°C, 12 hours at 30°C).

At the end of this cycling, it was observed that the mechanical and electrical characteristics of the battery had not been changed (at 22°C ± 2°C, the battery was restored to a capacity higher than 1.60 Ah).

4.2.2 Storage for 24 Hours

A 10-cell battery was subjected to the following cycle after being charged at -30°C: the temperature cycling is shown in the following graph



The relative humidity was approximately 90%.

After the test, the battery was restored to a capacity of 0.78 Ah at a current drain of 30 mA at -50°C.

4.3 Electrical Tests /7

4.3.1 Measurement of Capacity

The capacity of ambiant temperature and at low temperatures was measured systematically.

Capacity at ambiant temperature: the capacity of the battery at ambiant temperature was measured over a cycle defined as follows: charging at constant current, I = 160 mA (C/10) for 14 hours; discharging at constant current, I = 320 mA (C/5) until the battery voltage reached 11 V. Under these conditions, the capacity of the batteries was 1.65 ± 0.1 ampere-hours.

Capacity at low temperatures: the capacity at low temperatures of the battery was measured over the following cycles: charging at constant current I = 40 mA for 30 hours (θ = 30°C); discharged at constant current, I = 30 mA, until the battery voltage reached 11 V (θ = 60°C).

Under these conditions, the battery capacity must be higher than 600 mAh. Of the 67 batteries tested in the first batch, 58 had a capacity higher than 600 mAh.

4.3.2 Duration of Life in Cycling

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(See test procedure No. 70 CT/TA/EB/0511 EOLE/BLP). The batteries are used under a wide variety of conditions during this project. During the first phase (the only one performed up to now) we observed 3 cases of operation which seemed to us to be the most critical.

4.3.2.1 Objective of Test

Check battery A to see that the power is stable (coefficient of reflection equals zero). Check battery B for operation in the case of overcharging at low temperatures (reflection coefficient equals zero).

4.3.2.2 Definition of Cycle

Duration of a cycle is 24 hours. Pressure is 200 m bars. Day sequence is 12 hours at a temperature of -25°C. The nightly sequence is 12 hours at a temperature of -50°C.

4.3.2.3 Daily Sequence

Only inspection operation is performed (38 mA). The battery is connected to the terminals of a power supply which simulates the solar generator: battery A, Igs = 27 mA; battery B, Igs = 50 mA.

4.3.2.4 Nightly Sequence

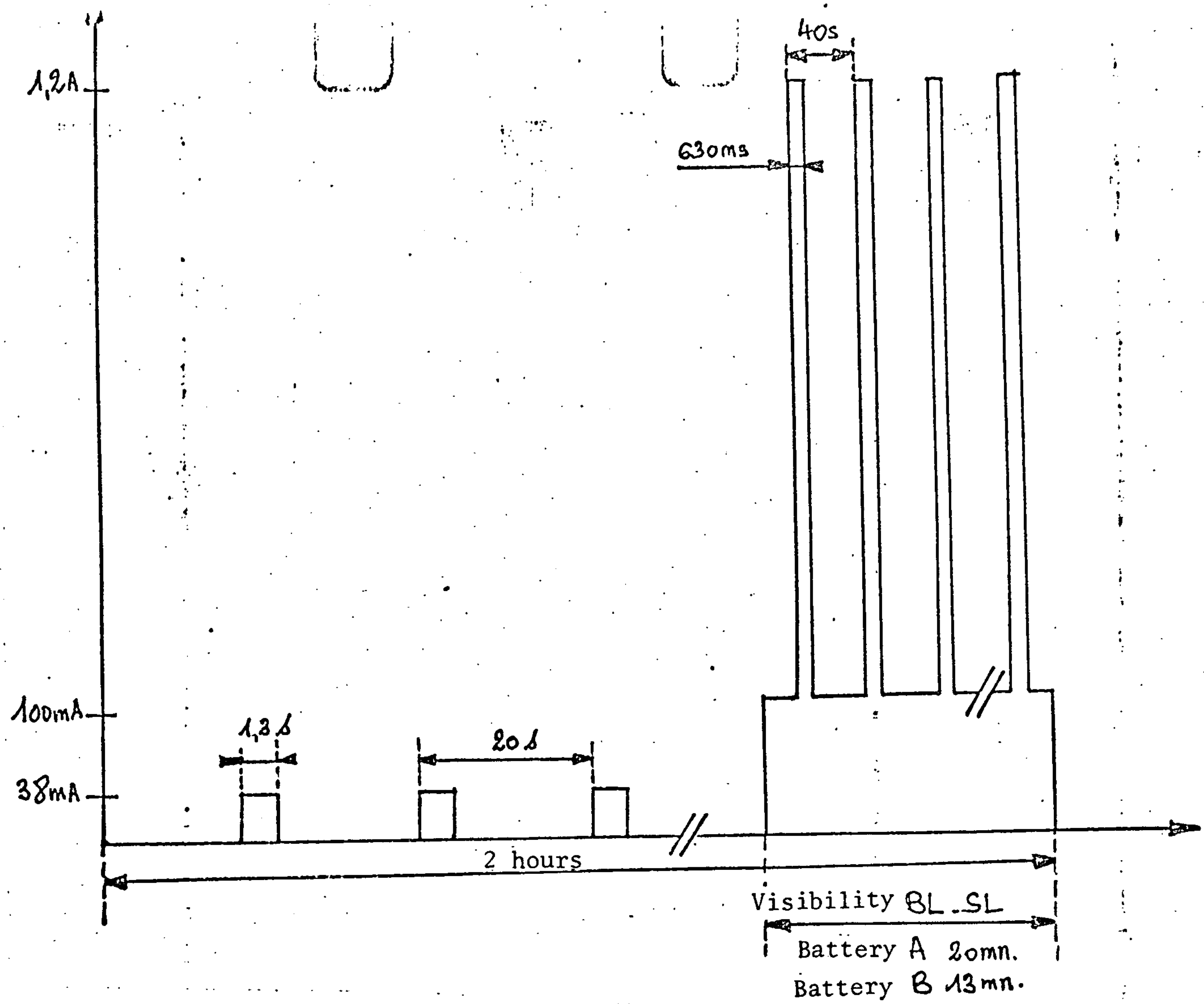
All the sequences for balloon satellite visibility (corresponding to the higher rates of consumption) is scheduled for nighttime.

The night sequence is divided into 6 periods or 2 hours each, for this the consumption diagram is shown as follows:

(see following page for diagram)

4.3.2.5 Results

1) Battery B, which was subjected to overcharging, operated properly for about 50 cycles, although some of the cells suffered breakage of supports and leaks beginning with the first cycle. After the 50th cycle, the distinct increase in voltage drop produced progressive drying of the cells. The cycling was stopped after 65 cycles since the power available at the battery terminals was insufficient to insure the operation of the nacelle.



2) Cycling of battery A (being conducted) was performed normally for 90 cycles (3 months).

Approximately the first 60 cycles were performed in accordance with the procedure defined above.

The following cycles were performed after addition of the charge regulator and regulation of the charging current at 50 mA.

5. Conclusion

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Inspite of the few results obtained, especially concerning lifetime, the results are extremely promising. In fact, they demonstrated that the type of cells developed is capable of operating in the Eole for more than 3 months provided that the battery is not overcharged. Many additional tests are necessary and a test program to check the functioning over the entire temperature range is now being studied.

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